REMARKS

Rejections under 35 USC §103(a)

Claims 1, 3, 4 and 6 were rejected under 35 USC §103(a) as being obvious over Shakuda (U.S. Patent No. 5,838,029) in view of Kinoshita et al ("Zirconium Diboride (0001) as an Electrically Conductive Lattice Matched Substrate for Gallium Nitride").

Claims 1 and 3 have been cancelled.

Claim 4 has been amended to recite "a first step of forming a low-temperature buffer layer consisting of $B_xAl_yGa_zIn_{1-x-y-z}N$ ($0 \leq x \leq 1, 0 \leq y \leq 1, 0 \leq z \leq 1, 0 \leq 1-x-y-z \leq 1$), on a ZrB_2 single crystal base having a defect density of 10^7 cm^{-2} or less, at a base temperature which does not give an energy greater than a surface potential of said ZrB_2 single crystal base to a nitrogen atom arising from the decomposition of buffer layer forming gas, allowing said low-temperature buffer layer to be grown or deposited on said ZrB_2 single crystal base substantially without creation of any Zr – B – N amorphous nitrided layer as a result of the diffusion and/or chemical bonding of the nitrogen atom, wherein said low-temperature buffer layer has a thickness in the range of 10 nm to 1 μm capable of suppressing the nitriding of the surface of said ZrB_2 single base, and said low-temperature buffer layer is formed as a single crystal at the time said first step is completed." Claim 6 also has been amended to recite "a first step of forming a low-temperature buffer layer consisting of

$B_xAl_yGa_zIn_{1-x-y-z}N$ ($0 \leq x \leq 1, 0 \leq y \leq 1, 0 \leq z \leq 1, 0 \leq 1-x-y-z \leq 1$) wherein said low-temperature buffer layer has a thickness in the range of 10 nm to 1 μm, on a ZrB_2 single

crystal base having a defect density of 10^7 cm^{-2} or less, at a base temperature which does not give an energy greater than a surface potential of said ZrB_2 single crystal base to a nitrogen atom arising from the decomposition of buffer layer forming gas, allowing said low-temperature buffer layer to be grown or deposited on said ZrB_2 single crystal base substantially without creation of any Zr – B – N amorphous nitrided layer as a result of the diffusion and/or chemical bonding of the nitrogen atom, wherein said low-temperature buffer layer has a thickness in the range of 10 nm to 1 μm capable of suppressing the nitriding of the surface of said ZrB_2 single base." These amendments are supported in the specification, for example at page 11, lines 7-12 and page 12, line 11 to page 13, line 11.

Responding to Applicants' previous response, the Office Action alleged as follows:

> The rejection of record is Shakuda in view of Kinoshita et al. Kinoshita et al is used to modify Shakuda. Shakuda teaches the deposition of a low temperature buffer on a substrate and a single crystal layer formed on the buffer. The modification is the use of the ZrB_2 substrate taught by Kinoshita et al. Kinoshita et al clearly suggests the use of ZrB_2 as a substrate for GaN because of the close lattice mismatch. Applicant's arguments appear to be directed to modifying the Kinoshita et al reference by including the buffer layer taught by Shakuda but that is not the rejection of record. Therefore, it would have been obvious to a person of ordinary skill in the art at the time of the invention to modify Shakuda, which includes the deposition of a low temperature buffer and a single crystal layer on a substrate, by using a ZrB_2 substrate, as suggested by Kinoshita et al because of the desirably close lattice match.

However, the situation will not be different in either way. Shakuda discloses growing a gallium nitride type compound semiconductor layer on a single crystal semiconductor substrate. Shakuda also discloses that it is preferable that the single crystal semiconductor substrate is made

of one selected from GaAs, GaP, InP and Si and has a (111) crystal plane. Thus, a person of ordinary skill in the art cannot simply replace the single crystal semiconductor substrate made of GaAs, GaP, InP and Si having a (111) crystal plane to a ZrB_2 single crystal base.

Moreover, a nitride semiconductor epitaxial growth using a ZrB_2 single crystal base practically involves particular difficulties in epitaxially growing a nitride semiconductor crystal. In view of the problems arising during the course of epitaxially growing a nitride semiconductor on a ZrB_2 single crystal base, the present inventors found a method which takes full advantages of the properties or features of the ZrB_2 single crystal base so as to achieve a high-quality nitride single-crystal semiconductor layer with an element-forming surface having a low dislocation density, through a fully simplified process.

The inventors found that in a process of forming an AlGaN-based nitride semiconductor film, even if a surface of a ZrB_2 single crystal base is originally clean, a Zr-B-N amorphous nitrided layer is formed before an AlGaN-based low-temperature buffer layer is formed. This is due to the diffusion/chemical bonding of a nitrogen atom arising from the decomposition of film-forming gas etc. to the surface of the ZrB_2 single crystal base, and the amorphous nitrided layer substantially precludes the growth of AlGaN-based nitride semiconductor or leads to the formation of island-shaped AlGaN-based nitride semiconductors, to cause the deterioration in surface smoothness of a grown layer and a number of defects in fused regions between the islands, resulting in the difficulty of AlGaN-based single crystal growth.

The present FIG. 4 shows a transmission electron micrograph where the section of an AlGaN-based semiconductor layer is formed with such a Zr-B-N amorphous nitrided layer. As seen in the micrograph, a six-sided-pyramid-shaped microcrystal domain is formed, and the dislocation density of the entire element-forming surface is unmeasurably increased to preclude the AlGaN-based semiconductor layer from applying to any device production.

The inventors also found that the formation of Zr-B-N amorphous nitrided layer can be prevented by controlling the temperature range. If the ZrB_2 single crystal base is controlled to be equal to or less than a certain temperature of the base (hereinafter referred to as "base temperature") meeting a requirement of allowing the growth or deposition of an AlGaN-based low-temperature buffer layer, raw materials of the low-temperature buffer layer can be supplied onto the surface of the base before and during the formation of the low-temperature buffer layer, without nitriding of the surface of the base, and successively an AlGaN-based single crystal film can be epitaxially grown to produce a low-dislocation-density high-quality AlGaN-based semiconductor substrate.

These are not recognized or discussed in Shakuda and Kinoshita et al. Thus, Shakuda and Kinoshita et al do not teach or suggest "a first step of forming a low-temperature buffer layer consisting of $B_xAl_yGa_zIn_{1-x-y-z}N$ ($0 \leq x \leq 1, 0 \leq y \leq 1, 0 \leq z \leq 1, 0 \leq 1-x-y-z \leq 1$), on a ZrB_2 single crystal base having a defect density of 10^7 cm^{-2} or less, at a base temperature which does not give an energy greater than a surface potential of said ZrB_2 single crystal base to a nitrogen atom arising from the decomposition of buffer layer forming gas, allowing said low-temperature

buffer layer to be grown or deposited on said ZrB_2 single crystal base substantially without creation of any Zr – B – N amorphous nitrided layer as a result of the diffusion and/or chemical bonding of the nitrogen atom, wherein said low-temperature buffer layer has a thickness in the range of 10 nm to 1 μm capable of suppressing the nitriding of the surface of said ZrB_2 single base, and said low-temperature buffer layer is formed as a single crystal at the time said first step is completed," as recited in claim 4. Similarly, Shakuda and Kinoshita et al do not teach or suggest "a first step of forming a low-temperature buffer layer consisting of $B_xAl_yGa_zIn_{1-x-y-z}N$ ($0 \leq x \leq 1, 0 \leq y \leq 1, 0 \leq z \leq 1, 0 \leq 1-x-y-z \leq 1$) wherein said low-temperature buffer layer has a thickness in the range of 10 nm to 1 μm, on a ZrB_2 single crystal base having a defect density of 10^7 cm^{-2} or less, at a base temperature which does not give an energy greater than a surface potential of said ZrB_2 single crystal base to a nitrogen atom arising from the decomposition of buffer layer forming gas, allowing said low-temperature buffer layer to be grown or deposited on said ZrB_2 single crystal base substantially without creation of any Zr – B – N amorphous nitrided layer as a result of the diffusion and/or chemical bonding of the nitrogen atom, wherein said low-temperature buffer layer has a thickness in the range of 10 nm to 1 μm capable of suppressing the nitriding of the surface of said ZrB_2 single base," as recited in claim 6.

For at least these reasons, claims 4 and 6 patentably distinguish over Shakuda and Kinoshita et al.

In view of the aforementioned amendments and accompanying remarks, Applicants submit that that the claims, as herein amended, are in condition for allowance. Applicants request such action at an early date.

If the Examiner believes that this application is not now in condition for allowance, the Examiner is requested to contact Applicants' undersigned attorney to arrange for an interview to expedite the disposition of this case.

If this paper is not timely filed, Applicants respectfully petition for an appropriate extension of time. The fees for such an extension or any other fees that may be due with respect to this paper may be charged to Deposit Account No. 50-2866.

Respectfully submitted,

WESTERMAN, HATTORI, DANIELS & ADRIAN, LLP

Sadao Kinashi

Sadao Kinashi
Attorney for Applicants
Registration No. 48,075
Telephone: (202) 822-1100
Facsimile: (202) 822-1111

SK/ar